Surgical repair of descending thoracic and thoracoabdominal aortic aneurysm involving the distal arch: Open proximal anastomosis under deep hypothermia versus arch clamping technique

Jae Suk Yoo, MD, Joon Bum Kim, MD, PhD, Sung-Ho Jung, MD, PhD, Suk Jung Choo, MD, PhD, Cheol Hyun Chung, MD, PhD, and Jae Won Lee, MD, PhD

Background: Surgical repair of a descending thoracic and thoracoabdominal aortic aneurysm (DTA/TAAA) involving the distal arch is challenging and requires either deep hypothermic circulatory arrest (DHCA) or cross-clamping of the distal arch. The aim of this study was to compare these 2 techniques in the treatment of DTA/TAAA involving the distal arch.

Methods: From 1994 to 2012, 298 patients underwent open repair of DTA/TAAA through a left thoracotomy. One hundred seventy-four patients with distal arch involvement who were suitable for either DHCA (n = 81) or arch clamping (AC; n = 93), were analyzed. In-hospital outcomes were compared using propensity scores and inverse-probability-of-treatment weighting adjustment to reduce treatment selection bias.

Results: Early mortality was 11.1% in the DHCA group and 8.6% in the AC group ($P = .58$). Major adverse outcomes included stroke in 16 patients (9.2%), low cardiac output syndrome in 15 (8.6%), paraplegia in 10 (5.7%), and multiorgan failure in 10 (5.7%). After adjustment, patients who underwent DHCA were at similar risk of death (odds ratio [OR], 1.14; $P = .80$) and permanent neurologic injury (OR, 0.95; $P = .92$) to those who underwent AC. Although prolonged ventilator support (>24 hours) was more frequent with DHCA than with AC (OR, 2.60; $P = .003$), DHCA showed a tendency to lower the risk of paraplegia (OR, 0.15; $P = .057$).

Conclusions: Compared with AC, DHCA did not increase postoperative mortality and morbidity, except for prolonged ventilator support. However, DHCA may offer superior spinal cord protection to AC during repair of DTA/TAAA involving the distal arch. (J Thorac Cardiovasc Surg 2014;148:2101-7)

Open surgical repair of a descending thoracic aortic and thoracoabdominal aortic aneurysm (DTA/TAAA) involving the distal arch is challenging because simple proximal DTA crossclamping is not always possible and either deep hypothermic circulatory arrest (DHCA) or clamping of the aortic arch may be required to achieve proximal anastomosis.[1,2] The advantages of DHCA are cited as excellent protections for the spine and visceral organs, a bloodless field, and no need for aortic crossclamping.[3-5] Conversely, more time is required to decrease and increase the body temperature, as a result of which the risk of coagulopathy, systemic inflammatory response, cold pulmonary and myocardial damage, and left ventricular distention injury may be increased.[6,7] Moreover, with the advancements in various cardiopulmonary bypass (CPB) strategies and adjunct procedures for distal organ protection under mild or moderate hypothermia, profound hypothermia is no longer the only option for distal organ protection.[8-10] However, when the aneurysm involves the distal arch, arch clamping (AC) is the only viable alternative to DHCA. The AC technique is also controversial, however, because gaining proximal control of the aorta between the great vessels is often challenging and requires extreme caution in handling the aortic arch, especially in the presence of a "shaggy aorta."[11,12] Furthermore, temporary occlusion of the left subclavian artery (LSCA) may potentially reduce spinal cord perfusion and increase the risk of spinal cord ischemic injury.[11,13] There is currently no consensus on the optimal method for proximal control in open repair of DTA/TAAA involving the distal arch, and previous studies on this topic have been limited. Thus, the aim of this study was to compare the clinical outcomes of DHCA versus AC in the surgical repair of DTA/TAAA involving the distal arch.

METHODS

Patients

From January 1994 to December 2012, 298 patients underwent DTA/TAAA repair through a left thoracotomy or a thoracoabdominal approach. Seventy-three patients whose aortic pathology did not involve the aortic

From the Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, South Korea.

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Address for reprints: Joon Bum Kim, MD, PhD, Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, 388-1 Pungnap-dong Songpa-gu, Seoul 138-736, South Korea (E-mail: jbkim1975@amc.seoul.kr).

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Abbreviations and Acronyms

AC	= arch clamping
CI	= confidence intervals
CPB	= cardiopulmonary bypass
CSF	= cerebrospinal fluid
CT	= computed tomography
DHCA	= deep hypothermic circulatory arrest
DTA/TAAA	= descending thoracic and thoracoabdominal aortic aneurysm
LSCA	= left subclavian artery
LV	= left ventricle
SVG	= saphenous vein graft

arch and allowed proximal DTA clamping were excluded. Distal arch involvement was defined as an aneurysm occurring at the isthmus level or one that involved the distal arch (Figure 1), so that simple crossclamping of the proximal DTA was impossible. Fifty-one patients with distal arch involvement for whom there was no alternative but to use DHCA were also excluded. Thus, 174 patients in whom either DHCA or AC was deemed possible were included in this study; 81 patients underwent DHCA and 93 patients underwent AC. The 174 procedures in this study were performed by 5 different surgeons. The use of the DHCA technique for each surgeon was as follows; A (46 of 86; 53.5%), B (7 of 27; 25.9%), C (4 of 26; 15.4%), D (17 of 23; 73.9%), and E (7 of 12; 58.3%). Some surgeons have favored open proximal anastomosis under DHCA, and others have tried to crossclamp the arch by any means possible. For extensive TAAA disease regardless of distal arch involvement, some surgeons preferred DHCA, based on the belief that profound hypothermia might offer superior protection to the spinal cord and distal organs. The choice of DHCA versus AC was primarily at the attending surgeon's discretion.

The present study protocol was approved by the ethics committee and institutional review board of our institution, and informed consent from individual patients was waived because of the retrospective nature of the study.

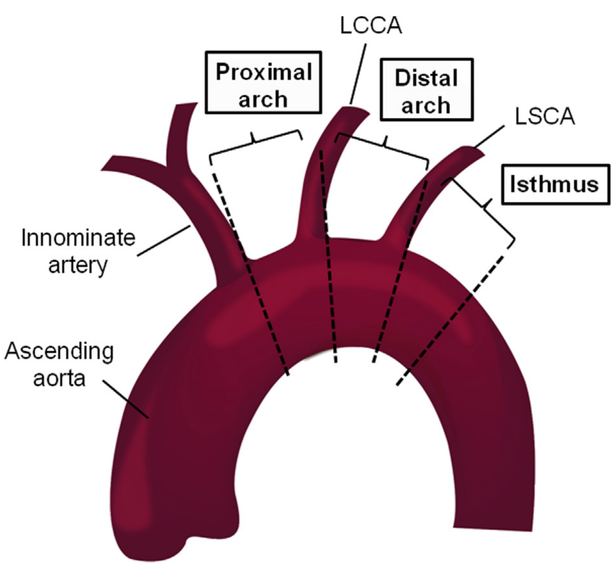

FIGURE 1. Aortic arch anatomy. *LCCA*, Left common carotid artery; *LSCA*, left subclavian artery.

Operative Technique

Patients were intubated with a double-lumen endotracheal tube. All procedures were performed through a left posterolateral thoracotomy or a thoracoabdominal approach via the fifth or sixth intercostal space. The DTA and abdominal aorta were dissected free to allow proximal and distal crossclamping and resection of the pathologic segments. The left femoral artery and vein were exposed through an oblique incision in the inguinal crease. After heparin sodium (3 mg/kg) was administered, arterial and venous cannulation was established with a wire-directed approach. Transesophageal echocardiography was used to monitor the placement of the venous catheter in the right atrium. Vacuum-assisted venous drainage was used and additional cannulation was applied through the pulmonary artery when the flow was insufficient.

DHCA was used in 81 patients (46.6%) and AC was used under partial femoro-femoral CPB in 93 patients (53.4%). Of the 81 patients who underwent DHCA, the lowest nasopharyngeal temperature was 12 to 15°C in 28 (34.6%), 15 to 18°C in 33 (40.7%), and 18 to 22°C in 20 (24.7%). In the early period, surgeons preferred severe profound hypothermia based on the belief that it could provide superior protection to the spinal cord or other end organs. Recently, however, even surgeons who prefer DHCA for proximal control in our institution usually aim for a nasopharyngeal temperature not lower than 20 to 24°C, because proximal anastomosis takes 15 to 20 minutes. A left atrial (LA) vent through the left superior or inferior pulmonary vein was used in 36 (44.4%) patients in the DHCA group, and cardioplegia was not used. When the desired nasopharyngeal temperature was reached, circulatory arrest was initiated and the aorta was opened. Proximal aortic anastomosis was performed with a branched vascular graft in an open fashion without any selective antegrade cerebral perfusion techniques, after which extraarterial cannulation was added through the side branch of the graft so that dual perfusion to both the upper and lower body could be achieved. After placing a crossclamp distal to the side branch, partial CPB flow to the upper body was reinstituted. During the open proximal anastomosis under DHCA, the patient was placed in the Trendelenburg position, and while reinstituting upper body perfusion via the sidearm branch of the graft, the deairing procedure was performed at the same time, shortly before completing the proximal anastomosis.

In the AC group, the body temperature was lowered to 30 to 35°C. Distal arch and separate LSCA clamping was conducted with beating-heart status. After proximal anastomosis, crossclamping was moved proximal to the graft. Distal anastomosis was performed in an open fashion when distal clamping was not feasible. When aortic replacement involved a visceral or renal segment, visceral/renal perfusion with cold blood was performed using separate balloon cannulas. After completion of the anastomoses, full CPB was resumed to both the upper and lower body. Cerebrospinal fluid (CSF) drainage was used routinely as an adjunct for spinal protection when the disease involved the aorta at the level between the T8 and L2 vertebrae (n = 105, 60.3%).

Statistical Methods

Categorical variables are presented as frequencies and percentages, and continuous variables are expressed as the mean ± standard deviation or the median with the range. Differences in baseline characteristics were compared using the unpaired *t* test or Mann-Whitney *U* test for continuous variables, and the χ^2 test or the Fisher exact test for categorical variables, as appropriate. To reduce the impact of treatment selection bias and potential confounding in this observational study, we robustly accounted for significant differences in patient characteristics using weighted logistic regression analysis and inverse probability of treatment weighting.[14] With this technique, weights for patients undergoing DTA/TAAA repair using DHCA were the inverse of the propensity scores, and weights for patients using the AC technique were the inverse of 1 − propensity scores. Stabilized weights were used to reduce the weights of treated patients with low propensity scores and untreated patients with high propensity scores.[15] Propensity scores were estimated by multiple logistic regression analysis.